Integration of Model Large-Scale Environmental Diagnostics for Tropical Cyclones into the MET-TC Verification Package

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Background: METplus

- Enhanced Model Evaluation Tools, https://dtcenter.org/community-code/metplus
- The Model Evaluation Tools (MET: https://dtcenter.org/community-code/model-evaluation-tools-met) were developed over a decade ago by the National Center for Atmospheric Research (NCAR) under the auspices of the Developmental Testbed Center (DTC) to replicate one of the NOAA Environmental Modeling Center's (EMC) verification packages.
- A suite of tools replicating NHC's verification capabilities were added later to expand MET capabilities. The goal was to have a community tool that was platform independent and extensible.
- More recently, a suite of Python wrappers have been developed to form the METplus framework that includes MET along with Python aggregation and plotting capability.
- It is supported for the community via the DTC with a growing community of developers.

Background: Environmental Diagnostics

- TC forecasters have long relied on the analysis of the TC environment as a significant part of their forecast process
- The TC environment and its relationship with TC evolution has been quantified as part of statistical-dynamical guidance for decades, including the Statistical Hurricane Intensity Prediction Scheme (SHIPS)
- The large-scale TC environmental diagnostics assess the environment from a storm-centered perspective, calculating the diagnostics using pre-determined radii from the current or forecast position of the TC center.

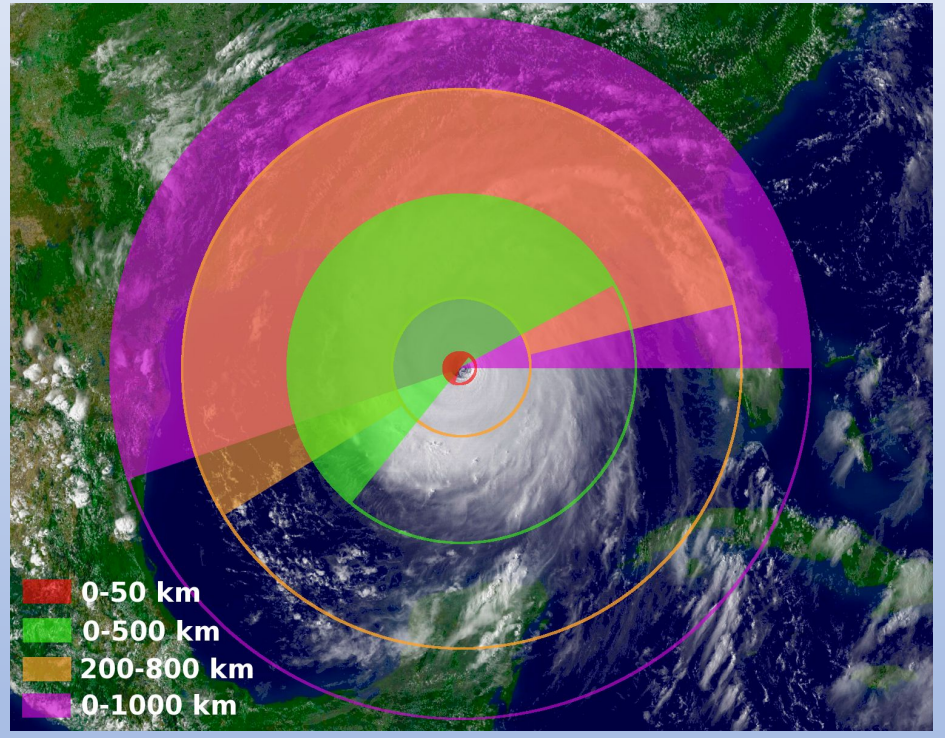

Image courtesy of Brian McNoldy

Sea surface temp (RSST)
850-200 mb shear (SHDC); 200 mb zonal wind (U20C)
200 mb temp (T200); 850-700 mb RH (RHLO)
700-500 mb RH (RHMD); 500-300 mb RH (RHHI)
200 mb divergence (D200); 850 mb vorticity (Z850)

Background: Environmental Diagnostics

- The diagnostics fall into three general categories, sounding, storm, and custom, and output into a human-readable file
- The diagnostics:
  - serve as input for statistical-dynamical models,
  - are used directly by forecasters for real-time model assessment (in additional formats), and
  - are useful for model evaluation and intercomparison

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*   HWRF  2020103118   *
*   AL29  TWENTY-NI    *

------------------------------------------------------------     STORM DATA     ------------------------------------------------------------

NTIME 022   DELTAT 006
TIME     (HR)        0     6    12    18    24    30    36    42    48    54    60    66    72    78    84    90    96   102   108   114   120   126
LAT      (DEG)    14.7  15.4  15.6  15.6  15.7  16.1  16.3  16.7  16.6  16.4  15.9  15.5  15.3  15.3  15.0  14.9  14.6  14.2  14.4  15.5  15.9  16.1
LON      (DEG)   287.6 286.2 284.5 283.1 282.0 281.2 280.0 279.1 278.2 277.5 276.9 276.6 276.5 276.2 275.6 275.1 274.2 273.9 273.6 272.9 272.3 271.6
MAXWIND  (KT)       30    44    48    55    68    69    74    81    82   100    99   102    96    79    51    35    34    36    41    32    29    30
RMW      (KM)       60    48    26    17    15    16    17    17    19    22    19    20    20    15    58   103    99   136   138   170   113   146
MIN_SLP  (MB)     1008  1003   998   994   985   982   977   965   966   961   951   946   947   951   969   985   996  1000  1005  1004  1004  1004
SHR_MAG  (KT)        2     6     6     5     3     7    10    11    15    19    15    12    10     7     8     8     9    14    12     6     5     9
SHR_HDG  (DEG)      76    54    76    93    55    52    45    41     5   356   350   317   283   276   253   214   239   261   269   292   298   343
STM_SPD  (KT)       15    16    15    12     9    10    11     9     8     7     6     4     2     5     6     7     7     3     8    10     7     7
STM_HDG  (DEG)     297   287   274   272   285   287   287   280   259   241   224   213   243   251   249   254   239   251   323   320   296   287
SST      (10C)     293   290   290   291   291   290   294   290   291   291   290   283   269   257   228   222   212   200   199   218   259   263
OHC      (KJ/CM2) 9999  9999  9999  9999  9999  9999  9999  9999  9999  9999  9999  9999  9999  9999  9999  9999  9999  9999  9999  9999  9999  9999
TPW      (MM)       64    66    65    65    64    65    65    66    66    67    66    65    64    64    63    61    57    54    53    56    58    59
LAND     (KM)      256   289   256   236   235   222   278   310   232   172    92    37    12    -4   -70  -109  -134  -175  -149   -28     9    32
850TANG  (10M/S)    55    67    71    89   105   113   123   141   155   164   177   186   186   189   176   164   137   122   102   100    94    92
850VORT  (/S)       72    65    87    85    86    94   105   102   114    89   104   148   102   108   117   132   126   125   144   101   104    91
200DVRG  (/S)       12    46    28    67   109    97   134    91   132   108   134   130   120   107    88   100    86    92   103    93    73    80

------------------------------------------------------------    SOUNDING DATA    ------------------------------------------------------------

NLEV 027 SURF 1000 0975 0950 0925 0900 0850 0800 0750 0700 0650 0600 0550 0500 0450 0400 0350 0300 0250 0200 0150 0100 0070 0050 0030 0020 0010
TIME     (HR)        0     6    12    18    24    30    36    42    48    54    60    66    72    78    84    90    96   102   108   114   120   126
T_SURF   (10C)     286   276   274   268   266   268   259   259   258   256   249   245   249   252   248   250   253   260   255   248   250   249
R_SURF   (%)        80    54    55    55    57    57    61    59    60    63    63    65    65    66    68    67    64    64    66    64    64    65
P_SURF   (MB)      1011  1012  1011  1011  1011  1011  1011  1011  1010  1010  1010  1010  1010  1009  1010  1010  1010  1009  1010  1010  1010  1009
U_SURF   (10KT)   -106  -109  -108  -101   -90   -97   -80   -75   -44   -50   -30   -31   -26   -44   -36   -33   -14     1     6   -24   -11    -7
V_SURF   (10KT)     -6   -25    -4   -13     1   -14   -37   -44   -71   -82   -63   -37   -12    -9     1    -1    -5    -7    -4   -10     4    -7
T_1000   (10C)     280   276   273   271   272   271   265   264   267   264   259   259   263   264   262   261   264   265   262   259   259   258
R_1000   (%)        74    78    78    79    80    80    83    81    81    81    82    83    82    82    84    83    82    82    84    82    82    82
Z_1000   (DM)        9    11    10    10     9    10     9     9     9     8     9     8     8     8     8     8     8     8     9     8     8     8
U_1000   (10KT)   -115  -126  -121  -115  -101  -108   -91   -84   -53   -60   -38   -39   -32   -49   -43   -39   -18    -1     6   -28   -17   -13
V_1000   (10KT)     -7   -29    -4   -12     1   -15   -41   -53   -81   -93   -74   -43   -16   -12    -1    -4    -7    -6    -1   -10    -3   -19
T_0010   (10C)     -426  -417  -427  -454  -427  -409  -432  -456  -432  -418  -428  -439  -424  -420  -434  -441  -427  -434  -442  -437  -433  -431
R_0010   (%)          0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
Z_0010   (DM)      3106  3108  3108  3101  3107  3107  3104  3099  3103  3104  3103  3099  3105  3104  3102  3100  3104  3101  3101  3103  3103  3101
U_0010   (10KT)    -84     8   -85  -132   -98    48   -93  -202  -129   -28   -26   -69   -88   -59   -53   -75   -92   -47   -29    -1   -54   -13
V_0010   (10KT)     40   -83    29   -50    93    42  -148   -13    98    42   -30   -53    17   -20   -47   -41    12    45    22     2    37     4

------------------------------------------------------------     CUSTOM DATA     ------------------------------------------------------------

NVAR 001
TGRD (10^7C/M)      1     9     6     8     8     6     8    15    25    31    32    29    25    13     8    13    19    23    18    14    19    19

------------------------------------------------------------      COMMENTS       ------------------------------------------------------------

*   SST, OHC averaged from    0-  50 km around storm center [x10 C, kJ/cm2]   *
*   RMW within    0- 200 km around storm center [km]   *
*   U, V, SHR averaged from    0- 500 km around storm center [x10 kt, x10 kt, kt]   *
*   850VORT, 200DVRG averaged from    0-1000 km around storm center [x10^7 /s, x10^7 /s]   *
*   850TANG averaged from    0- 600 km around storm center [x10 m/s]   *
*   T, R, Z, P averaged from  200- 800 km around storm center [x10 C, %, dm, mb]   *
*   TPW averaged from    0- 200 km around storm center [mm]   *
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Example model large-scale diagnostic file, for AL292020, pre-Hurricane Eta from the HWRF 1800 UTC 31 October 2020 model forecast. Diagnostics are split into three categories: storm, sounding, and custom, with comments on the calculations provided in an additional section.

Project Goals

- The main goal of this project is to transition diagnostic evaluation tools of the large-scale environment surrounding tropical cyclones (TC) into METplus.
  - Integrating TC diagnostics into METplus will make these diagnostic evaluation tools more accessible to forecasters, model developers, and researchers.

- Convert existing TC diagnostics package to Python and integrate into METplus verification system
- Verify fidelity to operational TC diagnostics
- Improve TC diagnostics package efficiency
- Develop documentation, use-case(s), and education training materials for TC large-scale diagnostics package in METplus

Project Milestones – Year 1

No.	Milestone Description	Planned (Revised) Date	Percent Complete
1	Assessment of existing capabilities within METplus and applicability to diagnostic software process	Oct 2021	100%
2	Development of the unit tests, case studies for potential points of failure in conversion of diagnostic calculations, integration framework	Oct 2021	100%
3	Conversion, integration, and testing of the re-gridding of model fields to the TC-centered coordinate system	Jan 2022	100%
4	Conversion, integration, and testing of underlying calculations for sounding, storm, and custom variable sections	Apr 2022	40%
5	Begin real-time demonstration and evaluation of large-scale diagnostics for 2022 Atlantic and East Pacific hurricane seasons in coordination with JHT	Jul 2022	10%
6	Complete initial documentation on large-scale diagnostic calculations, consistent with existing documentation of operational diagnostics	Jul 2022	25%

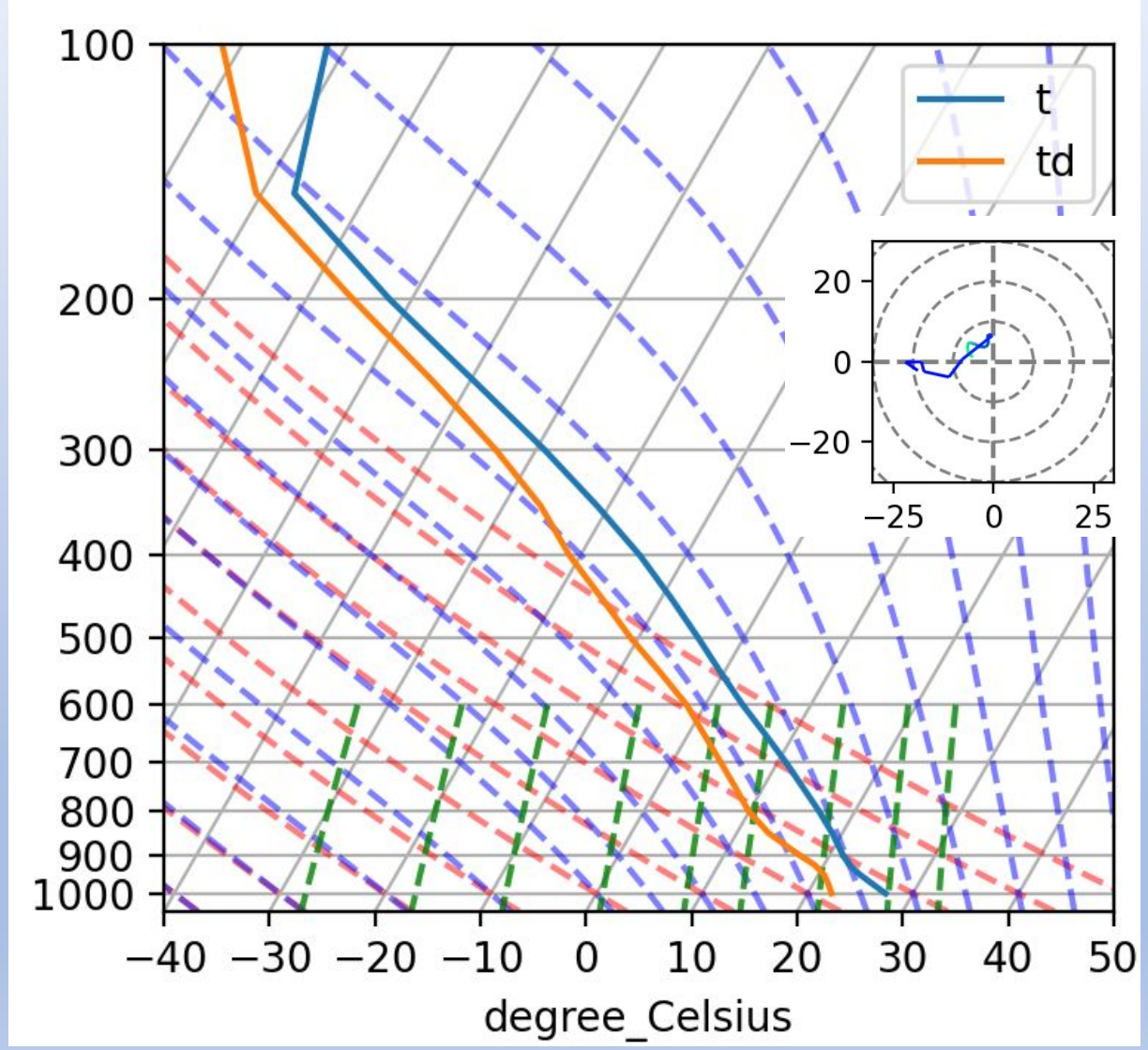
Current Progress

- Existing capabilities of METplus assessed – data ingest and regridding to TC-centric grid contained within METplus and MET-TC packages
- Data ingest, conversion to TC-centric cylindrical grid, and azimuthal area-averaging incorporated converted to Python for ingest into METplus (and comparison with existing METplus routines where appropriate)
- Comparison testing for fidelity to original version of TC diagnostic code underway
- Conversion of predictor calculations underway, completed for sounding section of diagnostics

Current Progress

- Skew-T showcasing calculations from the sounding section
- Thermodynamic predictors in the annulus 200-800km surrounding the TC center
- Dynamic predictors in the area 0-500km surrounding the TC center

- Case shown:
  - Tropical Storm Ida
  - 1200 UTC 27 August 2021
  - GFS – Analysis (Forecast hour 0)



Future Work

- Complete conversion, integration, and testing of underlying calculations for sounding, storm, and custom variable sections
- Coordinate real-time demonstration with JHT for 2022 hurricane season in Atlantic and East Pacific basins
- Present at the 35th AMS Conference on Hurricanes and Tropical Meteorology in May 2022
- Complete initial documentation on large-scale diagnostic calculations, consistent with existing documentation of operational diagnostics